FINAL REPORT
Saratoga Horticultural Research Endowment
2016

Developing Irrigation Guidelines for the Establishment of California Native Plants in the Landscape - Year 2

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INTRODUCTION

Competition for unreliable water resources followed by five years of drought led California to develop strict regulations about urban landscape water use (Department of Water Resources, 2015; Executive Dept., 2015). Though the trend toward using drought-adapted and low-water use plants has been growing slowly for a decade or more, the drought has brought a greater awareness to the significance of the role of low-water plants play in reducing landscape water use while maintaining ecosystem and aesthetic services (Hilaire, 2008). Most California native plants, like those from other Mediterranean climates, are adapted to high heat and little or no summer water, and are therefore often recommended as replacements for plants with higher water needs originating from climates unlike our own. There is, however, a common problem reported by landscape professionals and amateur gardeners alike: many California native species sold for landscapes die during their first year in the ground. This results in nurseries often having to replace the plants at their cost, and may discourage further use of native plants in urban landscapes. The issue is irrigation during establishment: the most common cause of failed establishment of California native plants is inappropriate application of water. Almost all plants require more water, more frequently, in their first year of establishment than they do in subsequent years. The perception that low-water use plants are immediately drought tolerant upon planting can lead to under-watering, resulting in death (Bornstein et al., 2005). Conversely, some species will not tolerate saturated soil conditions during warm weather, especially in heavy soil. Good information providing practical guidelines on how to irrigate these plants during their first year is scarce.

Although it is generally recommended to plant native perennials in the fall, when weather cools down and roots can take advantage of the seasonal moisture, landscape development and installation is subject to timeline constraints that require spring or even summer planting. However, even with ideal fall planting, many natives still require supplemental water during their first summer. With statewide restrictions in place requiring new landscape plans to show conservative water use budgets, many of the plants specified in those development plans are low-water use California native species and cultivars. It will greatly benefit nurseries, landscape professionals, and homeowners if establishment irrigation regimes are available to provide for the best first-year survival rates and performance of commonly used California natives.

During the growing season of 2016, the researchers grew five plant species on different irrigation schedules designed to replace four levels of available soil moisture depletion. Since irrigation scheduling and plant performance sometimes varies by soil type, the experimental design was duplicated in two commonly found soil types, clay loam and sandy loam. These five species were chosen because they were widely available California natives that are commonly used in urban landscapes.

The goal of the study was to evaluate the establishment performance of these five species when planted in the spring, and develop recommended establishment irrigation guidelines for these species in these two soil types. We plan to make these and the Year 1 trials results widely available to nurseries, landscape architects and designers, landscape managers, and homeowners. Using these recommendations should greatly increase the chances of successful landscape establishment of these California native species with greater customer satisfaction and fewer nursery replacements.

Table 1. Species planted in April 2016 in Davis, CA and Woodbridge, CA.

Botanical Name	Common name
Arctostaphylos 'Emerald Carpet'	Emerald carpet manzanita
Baccharis pilularis 'Pigeon Point'	Dwarf coyote brush
Ceanothus griseus horizontalis 'Yankee Point'	Yankee Point Ceanothus
Mimulus 'Trish'	Pink monkeyflower
Rhamnus californica 'Mound San Bruno'	Mound San Bruno coffeeberry

MATERIALS AND METHODS

Two fields were prepared to conduct irrigation trials in full sun. Located in Davis, CA, Field 1 has silty clay loam soil; Field 2 in Woodbridge, CA has fine sandy loam. Both fields are in USDA hardiness zone 9b and Sunset Zone 14. Each field was laid out with five rows with 24 planting spaces per row; rows and spaces were 2m apart. Six plants of each species on each of the four irrigation treatments were randomly placed in two complete blocks (north and south; three reps per treatment per species per block) for a total of 120 plants. The rows were covered with three inches (7.5cm) of chipped-wood mulch, and a ring of internal-emitter drip tubing with a combined application rate of 3.2gph (12.11 l/h) was laid beneath the mulch at the potting medium/native soil interface of each plant.

The soil from each field was sampled at field capacity, weighed, dried and weighed again to determine the water holding capacity (WHC); standardized charts were then used to estimate the total percentage of plant available water (AW) for each soil type (UCANR, 2009). An irrigation budget was developed for each field using four levels of Management Allowable Depletion (MAD) based on percentages of each soil type's AW at 25%, 50%, 75%, and 100%. The irrigation budget used daily Reference Evapotranspiration (ET_0) accumulation, as described in the California Irrigation Management Information System (CIMIS, 2017). Data was retrieved daily from CIMIS Station #6 for Field 1 and from an onsite private weather station for Field 2.

Plant width, length, and height measurements were taken monthly. A plant growth index (PGI) was calculated to quantify the comparative growth of plants under different irrigation treatments using the formula [(l +w)/2 +h]/2, where *l*, *w*, and *h* represent length, width, and height of the plant (Irmak et al, 2004). Relative PGI was calculated to make up for initial plant size differences using the formula (monthly PGI/initial PGI). Potential differences in PGI were analyzed using ANOVA and Tukey's HSD test. Qualitative performance ratings on a scale of 1-5 were made

monthly in the following categories: foliage appearance, flowering abundance, pest tolerance, disease resistance, vigor, and overall appearance- the "WOW" factor- (Standardized Trialing Protocol, 2015).

Midday water potential was measured in summer (June and July) and again in fall (September) using a pressure chamber (SoilMoisture Equipment Corp., Goleta, CA). Measurements were taken before and after each irrigation event for each treatment. Our initial proposed protocols were altered to reflect the recommended method for most effectively evaluating plant water stress vis-à-vis irrigation timing (Shackel, 2014). Several problems were encountered however. Three of the plants species (*Arctostaphylos, Baccharis, and Mimulus*) did not have internode lengths that made use of the instrument feasible. Researchers collected 1 stem from each *C*. 'Yankee Point' and *R*. 'Mound San Bruno' of each treatment being measured. Requirements for stem selection 1) healthy, actively growing & containing no damage, 2) internode length of 0.5-1" below 1-2" of stem and leaves. At the outset of each collecting period stem sections were selected for all *Ceanothus* and *Rhamnus* corresponding to the treatment to be measured and covered with a foil envelope to exclude light and halt photosynthesis. After a 10-minute waiting period stems were harvested as needed minimizing time between leaf excision and chamber pressurization to 15-60s. Pressure was applied until water began to be exuded from the xylem.

Collecting transpiration measurements using a Decagon porometer was abandoned after researchers encountered similar morphological constraints and environmental conditions that rendered the instruments unsuitable for this trial.

RESULTS AND DISCUSSION

For most irrigation treatments, plants grown in sandy loam showed lower mortality than those grown in clay loam, presumably because the greater soil porosity prevents oversaturated conditions which could lead to root rotting immediately following an irrigation event. Tables 2 and 3 below summarize for each site the final growth percentage (relative plant growth index or rPGI), percent mortality, and final overall appearance rating on each irrigation treatment for the species evaluated. It is helpful to keep in mind that the 100% MAD treatment was irrigated the least frequently and 25% MAD was irrigated the most frequently. At 100% MAD, essentially all the plant available water would be gone just as irrigation was applied.

These results show that some species either use water at a slower rate or are better at extracting water from the soil as it dries and requires increasing energy to overcome decreasing soil water potential. These species are more readily adapted to an infrequent irrigation schedule during establishment. A general ranking in both soils from least frequent to most frequent irrigation needed during establishment is *Baccharis* 'Pigeon Point', *Arctostaphylos* 'Emerald Carpet', *Ceanothus* 'Yankee Point' and *Mimulus* 'Trish', and *Rhamnus* 'Mound San Bruno'. These rankings and the recommended MAD percentages are based on a combination of mortality percentage and final overall appearance ratings. There were no significant differences in relative growth for any species on any treatment in either field during the establishment period. Suggested irrigation scheduling for each soil type by month is found in Tables 4 (clay) and 5 (sand). The intervals are based on historical reference evapotranspiration (ET_0) for the ET zones representative of the Central Valley, 12, 14, 15, and 16. http://wwwcimis.water.ca.gov/App_Themes/images/etozonemap.jpg. Additional data shown is inches of water and/or gallons of water to apply at each irrigation event. Photographs of each species near the end of the trial on the recommended MAD% are found in the Appendix.

The stem water potential data collected was inconsistent and inconclusive for the two species for which measurements were taken, *Ceanothus* 'Yankee Point' and *Rhamnus* 'Mound San Bruno'. Since most protocols for these measurements dictate using leaves from within a canopy, it is possible that the results were unsatisfactory because plants of this age do not have a significant canopy under which sample stems may be taken. Additionally, the size of the plants made it undesirable to sample additional stems from each plant. Although we were not able to correlate plant stress measurements with the mortality, measurement, and quality data, these other data were sufficient to confidently

make recommendations for establishment irrigation regimes for these cultivars in these two common soil types.

***Arctostaphylos* 'Emerald Carpet'**
The overall appearance of this groundcover manzanita was best in sandy soil with 50-75% establishment MAD. This fits with the native range of this cultivar which is coastal from Big Sur north to Mendocino. Some chlorosis was observed in Davis where the soil is neutral; not surprising since recommendations are for somewhat acidic soil for best performance (Bornstein, et al., 2005). Grown in clay soil, 25% MAD is too frequent for satisfactory survival; in sandy loam 100% MAD is too infrequent for acceptable establishment survival. 50% MAD yielded no mortality, acceptable appearance, and best growth in both soils. Monthly quality ratings are found in Tables 6a-b in the Appendix.

***Baccharis* 'Pigeon Point'**
There was no mortality for this cultivar in either soil type. The best combined growth and appearance ratings for both soils were at the 100% MAD level. In clay, the onset of flowering was higher on the 25% level, while in sandy soil it was at the 100% level. Monthly quality ratings are found in Tables 7a-b in the Appendix.

***Ceanothus* 'Yankee Point'**
This cultivar grown in clay soil had zero mortality on only one level of MAD, 75%. While there was no mortality in sandy soil, the best appearance by far was on the same level of MAD. Monthly quality ratings on all levels are found in Tables 8a-b in the Appendix.

***Mimulus* 'Trish'**
This pretty, pink cultivar of monkeyflower was eye-catching throughout the growing period with non-stop blooms. In clay loam soil, all MAD levels had some mortality except for 75%, which also had the highest growth and appearance ratings. The highest mortality was at 25% MAD – the most frequent level. In the sandy loam site, only the 25% MAD had any mortality, with the best combination of growth and quality also on the 75% level. Clearly this species does not like frequent irrigation, even during establishment on either soil type. Monthly quality ratings are found in Tables 9a-b in the Appendix.

***Rhamnus* 'Mound San Bruno'**
Mound San Bruno coffeeberry was by far the most drought-sensitive plant in the trials in clay with progressively greater mortality the less frequent the irrigation. Only the 25% MAD had 100% survival in clay loam, and it yielded marginally the highest ratings in sandy soil as well. Monthly quality ratings are found in Tables 10a-b in the Appendix.

Notes for landscape managers

- Consideration should be given to establishment hydrozoning, placing plants with similar establishment water needs together as well as grouping them by their water use category as shown in WUCOLS (http://ucanr.edu/sites/WUCOLS/).
- Evaluating soil type when planting natives is critical to successful plant selection and establishment.
- Tables 4 and 5 below show the recommended management allowable depletion percentage during the first irrigated growing season for spring planting of each of the listed plant species in these two soil types. These are based on average historical reference evapotranspiration (ET_0) for the four ET zones that cover the Central Valley of California. The careful irrigation manager

will pay attention to conditions on the ground, and make schedule adjustments for rain events, high winds, and unusually high or low temperatures for the season.

- These recommendations also assume that plants will be well-irrigated upon planting, and that the controllers used have a setting for "interval" or "days between watering". If only a one-week schedule is available, and the recommended interval is longer than 7 days, the amount of water applied will need to be reduced accordingly, but acceptable results may not be achieved, especially in the heavier soil types.
- Both gallons and inches of water to apply at each irrigation event shown. To use inches, the application rate of the system must be measured. If individual plant irrigation is used, the gallons/plant number will be more useful, but the combined emitter rate must also be measured, since manufacturer's specifications may be inaccurate.

Table 2. Final relative plant growth index[1] (RPGI), percent mortality, and overall appearance ratings (on a scale of 1-5) for 5 California native species grown in **silty clay loam soil in Davis, CA** from April to October 2016. The recommended management allowable depletion (MAD) is derived the combination of best ratings and growth and lowest mortality.

SPECIES	Percent of MAD				Rec.
	100	75	50	25	MAD
***Arctostaphylos* 'Emerald Carpet'**					**50-100**
Final rPGI	1.1	1.1	1.5	1.0	
% Mortality	0	16.7	0	33.3	
Final Overall Appearance Rating	3.2	3.4	3.0	3.5	
***Baccharis* 'Pigeon Point'**					**100**
Final rPGI	2.7	2.6	2.8	2.9	
% Mortality	0	0	0	0	
Final Overall Appearance Rating	4.5	3.5	4.0	3.7	
***Ceanothus* 'Yankee Point'**					**75**
Final rPGI	3.0	2.2	1.8	2.8	
% Mortality	50	0	33.3	66.7	
Final Overall Appearance Rating	3.7	3.0	3.3	4.0	
***Mimulus* 'Trish'**					**75**
Final rPGI	1.8	2.4	1.9	2.1	
% Mortality	33.3	0	33.3	50	
Final Overall Appearance Rating	3.3	3.5	3.0	3.3	
***Rhamnus* 'Mound San Bruno'**					**25**
Final rPGI	3.6	3.1	2.8	3.1	
% Mortality	50	33.3	16.7	0	
Final Overall Appearance Rating	3.7	4.0	3.8	4.0	

[1] There were no significant differences in relative plant growth indexes for any species on any treatment using ANOVA and Tukey's HSD test at ≤0.05. RPGI= PGI/initial PGI

Table 3. Final relative plant growth index[1] (RPGI), percent mortality, and overall appearance ratings (on a scale of 1-5) for 5 California native species grown in **fine sandy loam soil in Woodbridge, CA** from April to October 2016. The recommended management allowable depletion (MAD) is derived the combination of best ratings and growth and lowest mortality.

SPECIES	Percent of MAD				Rec
	100	75	50	25	MAD
Arctostaphylos **'Emerald Carpet'**					**50-75**
Final rPGI	1.5	1.6	1.9	1.8	
% Mortality	16.7	0	0	0	
Final Overall Appearance Rating	3.2	4.0	4.0	3.5	
Baccharis **'Pigeon Point'**					**100**
Final rPGI	3.2	2.8	3.0	2.8	
% Mortality	0	0	0	0	
Final Overall Appearance Rating	5.0	4.3	4.5	4.4	
Ceanothus **'Yankee Point'**					**75**
Final rPGI	2.6	2.4	2.0	1.8	
% Mortality	0	0	0	0	
Final Overall Appearance Rating	2.8	4.2	3.2	3.5	
Mimulus **'Trish'**					**75**
Final rPGI	2.2	2.7	2.7	2.5	
% Mortality	0	0	0	33.3	
Final Overall Appearance Rating	4.2	4.5	4.0	4.3	
Rhamnus **'Mound San Bruno'**					**25-50**
Final rPGI	3.0	3.3	2.5	3.1	
% Mortality	0	0	0	0	
Final Overall Appearance Rating	4.0	4.0	4.2	4.3	

[1] There were no significant differences in relative plant growth indexes for any species on any treatment using ANOVA and Tukey's HSD test at ≤0.05. RPGI= PGI/initial PGI

Table 4. Sample recommended first year irrigation scheduling for spring planting of 5 California native species in clay loam soils for 4 Central Valley ET zones.

CLAY LOAM			APR	MAY	JUNE	JULY	AUG	SEPT	OCT
	Rec. MAD %	ET Zone	interval in days						
Arctostaphylos **'Emerald Carpet'**	**50**	12	8	6	5	5	6	8	13
inches	1.4	14	8	6	5	5	6	7	11
gals/plant	7.2	15	8	6	5	5	6	8	12
		16	7	5	5	5	5	7	11
Baccharis **'Pigeon Point'**	**100**	12	16	12	11	11	12	16	25
inches	2.7	14	15	12	10	10	11	14	20
gals/plant	14.3	15	16	12	10	10	11	15	23
		16	13	10	9	9	10	13	20
Ceanothus **'Yankee Point'**	**75**	12	12	10	8	8	9	12	19
inches	2.1	14	12	9	8	8	9	11	16
gals/plant	10.8	15	12	9	8	8	9	11	18
		16	10	8	7	7	8	10	16
Mimulus **'Trish'**	**75**	12	12	10	8	8	9	12	19
inches	2.1	14	12	9	8	8	9	11	16
gals/plant	10.8	15	12	9	8	8	9	11	18
		16	10	8	7	7	8	10	16
Rhamnus **'Mound San Bruno'**	**25**	12	4	3	3	3	3	4	6
inches	0.7	14	4	3	3	3	3	4	5
gals/plant	3.5	15	4	3	3	3	3	4	6
		16	3	3	2	2	3	3	5

Table 5. Sample recommended first year irrigation scheduling for spring planting of 5 California native species in clay loam soils for 4 Central Valley ET zones.

SANDY LOAM			APR	MAY	JUNE	JULY	AUG	SEPT	OCT
	Rec. MAD %	ET Zone	interval in days						
Arctostaphylos **'Emerald Carpet'**	**50**	12	7	5	5	5	5	7	11
inches	1.2	14	7	5	4	4	5	6	9
gals/plant	6.3	15	7	5	5	5	5	7	10
		16	6	5	4	4	5	6	9
Baccharis **'Pigeon Point'**	**100**	12	14	11	9	9	11	14	22
inches	2.4	14	13	10	9	9	10	13	18
gals/plant	12.7	15	14	11	9	9	10	13	21
		16	12	9	8	8	9	12	18
Ceanothus **'Yankee Point'**	**75**	12	11	8	7	7	8	11	17
inches	1.8	14	10	8	7	7	8	9	14
gals/plant	9.5	15	10	8	7	7	8	10	15
		16	9	7	6	6	7	9	14
Mimulus **'Trish'**	**75**	12	11	8	7	7	8	11	17
inches	1.8	14	10	8	7	7	8	9	14
gals/plant	9.5	15	10	8	7	7	8	10	15
		16	9	7	6	6	7	9	14
Rhamnus **'Mound San Bruno'**	**25**	12	4	3	2	2	3	4	6
inches	0.6	14	3	3	2	2	3	3	5
gals/plant	3.2	15	3	3	2	2	3	3	5
		16	3	2	2	2	2	3	5

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APPENDIX

Table 6a. *Arctostaphylos uva-ursi* 'Emerald Carpet' average monthly ratings in clay loam soil on 4 levels of management allowable depletion following spring planting in 2016.

CLAY LOAM	May	June	July	Aug	Sept	Oct
Foliage						
100	4.0	4.2	4.5	4.0	4.2	**4.2**
75	5.0	5.0	5.0	4.2	4.8	**4.0**
50	4.5	4.5	4.5	4.2	3.8	**4.0**
25	3.8	4.6	4.2	4.8	4.0	**4.0**
Flowering						
100	1.0	1.0	1.0	1.0	2.0	**1.0**
75	0.0	0.0	0.0	0.0	0.0	**0.0**
50	4.5	2.5	5.0	4.0	3.0	**1.5**
25	1.0	0.0	0.0	0.0	0.0	**0.0**
Pest Tolerance						
100	5.0	5.0	5.0	5.0	5.0	**5.0**
75	5.0	5.0	5.0	5.0	5.0	**5.0**
50	5.0	5.0	5.0	5.0	5.0	**5.0**
25	5.0	5.0	5.0	5.0	5.0	**5.0**
Disease Resistance						
100	5.0	5.0	5.0	5.0	5.0	**5.0**
75	5.0	5.0	5.0	5.0	5.0	**5.0**
50	5.0	5.0	5.0	5.0	5.0	**5.0**
25	5.0	5.0	5.0	5.0	5.0	**5.0**
Vigor						
100	3.0	3.2	2.8	2.8	3.0	**3.5**
75	3.0	3.2	3.3	2.8	3.4	**3.4**
50	3.5	3.7	3.5	3.7	3.5	**3.7**
25	2.7	3.6	2.8	3.8	3.3	**4.3**
Overall Appearance						
100	2.7	2.7	3.0	2.7	2.9	**3.2**
75	3.0	3.2	3.3	3.4	3.4	**3.4**
50	3.3	3.0	3.3	3.3	3.2	**3.0**
25	2.7	3.4	2.6	3.2	3.0	**3.5**

Table 6b. *Arctostaphylos uva-ursi* 'Emerald Carpet' average monthly ratings in sandy loam soil on 4 levels of management allowable depletion following spring planting in 2016.

SANDY LOAM	May	June	July	Aug	Sept	Oct
Foliage						
100	4.5	5.0	4.0	5.6	4.4	**3.8**
75	5.0	4.8	4.7	4.2	4.2	**4.2**
50	4.5	4.3	4.5	4.2	4.2	**4.2**
25	4.8	4.8	4.8	4.7	4.3	**3.7**
Flowering						
100	0.2	0.8	0.0	0.0	0.0	**0.0**
75	0.0	0.0	0.0	0.0	0.0	**0.0**
50	0.0	1.5	1.7	1.7	0.8	**1.7**
25	0.0	0.0	0.0	0.8	0.0	**0.0**
Pest Tolerance						
100	5.0	5.0	5.0	5.0	5.0	**5.0**
75	5.0	5.0	5.0	5.0	5.0	**5.0**
50	4.8	4.8	5.0	5.0	5.0	**5.0**
25	5.0	4.8	5.0	5.0	4.8	**5.0**
Disease Resistance						
100	5.0	5.0	4.8	4.8	5.0	**5.0**
75	5.0	5.0	5.0	4.8	5.0	**5.0**
50	4.8	4.8	5.0	4.7	5.0	**5.0**
25	4.8	5.0	5.0	5.0	5.0	**4.8**
Vigor						
100	3.3	4.0	4.0	3.2	2.8	**2.6**
75	3.3	4.0	4.0	3.7	2.8	**3.3**
50	3.2	3.8	3.8	3.3	3.7	**3.7**
25	3.8	4.8	4.8	4.8	3.2	**3.7**
Overall Appearance						
100	3.5	4.0	3.6	3.2	3.4	**3.2**
75	3.8	3.8	3.8	3.7	3.3	**4.0**
50	3.3	3.8	4.0	3.8	3.7	**4.0**
25	4.0	4.0	4.0	4.2	3.7	**3.5**

Table 7a. *Baccharis pilularis* 'Pigeon Point' average monthly ratings in clay loam soil on 4 levels of management allowable depletion following spring planting in 2016.

CLAY LOAM	May	June	July	Aug	Sept	Oct
Foliage						
100	4.3	5.0	5.0	3.2	3.0	**3.3**
75	4.0	4.7	5.0	3.3	2.8	**3.2**
50	3.7	4.8	5.0	3.0	2.4	**3.6**
25	4.3	4.5	5.0	4.4	4.0	**3.7**
Flowering						
100	0.0	0.0	0.0	0.0	0.0	**5.0**
75	0.0	0.0	0.0	0.0	0.0	**3.2**
50	0.0	0.0	0.0	4.0	0.0	**3.8**
25	0.0	0.0	0.0	0.0	0.0	**3.5**
Pest Tolerance						
100	5.0	5.0	5.0	3.3	3.0	**3.3**
75	5.0	5.0	5.0	3.8	3.2	**3.5**
50	5.0	5.0	5.0	3.2	2.8	**3.4**
25	5.0	5.0	5.0	4.5	4.2	**3.7**
Disease Resistance						
100	5.0	5.0	5.0	5.0	5.0	**5.0**
75	5.0	5.0	5.0	5.0	5.0	**5.0**
50	5.0	5.0	5.0	5.0	5.0	**5.0**
25	5.0	5.0	5.0	5.0	5.0	**5.0**
Vigor						
100	2.8	3.8	3.8	3.5	3.3	**4.5**
75	2.5	2.8	3.0	3.2	3.0	**3.3**
50	2.3	3.6	3.4	3.6	3.4	**4.0**
25	3.0	3.5	3.8	4.0	3.7	**4.5**
Overall Appearance						
100	2.8	3.5	3.8	2.8	2.6	**4.5**
75	2.5	2.7	3.2	2.8	2.4	**3.5**
50	2.3	2.8	3.4	2.6	2.3	**4.0**
25	2.7	3.0	3.7	3.8	3.3	**3.7**

Table 7b. *Baccharis pilularis* 'Pigeon Point' average monthly ratings in sandy loam soil on 4 levels of management allowable depletion following spring planting in 2016.

SANDY LOAM	May	June	July	Aug	Sept	Oct
Foliage						
100	4.5	4.7	4.8	5.0	5.0	**5.0**
75	3.8	4.3	4.8	4.8	5.0	**5.0**
50	3.7	4.7	4.8	4.8	5.0	**5.0**
25	3.8	3.7	5.0	4.8	5.0	**4.6**
Flowering						
100	0.0	0.0	0.0	0.0	0.0	**2.2**
75	0.0	0.0	0.0	0.0	0.0	**1.5**
50	0.0	0.0	0.0	0.0	0.0	**1.2**
25	0.0	0.0	0.0	0.0	0.0	**1.2**
Pest Tolerance						
100	4.5	4.7	5.0	5.0	5.0	**5.0**
75	4.5	4.7	5.0	5.0	5.0	**5.0**
50	4.2	5.0	5.0	5.0	5.0	**5.0**
25	4.3	4.8	5.0	5.0	5.0	**4.6**
Disease Resistance						
100	4.8	5.0	5.0	5.0	5.0	**5.0**
75	4.8	5.0	4.8	5.0	5.0	**5.0**
50	5.0	5.0	5.0	5.0	5.0	**5.0**
25	4.7	4.3	5.0	5.0	5.0	**5.0**
Vigor						
100	4.3	4.6	4.8	5.0	5.0	**5.0**
75	3.5	4.2	4.7	4.8	5.0	**4.8**
50	3.6	4.7	5.0	5.0	4.8	**5.0**
25	3.0	3.8	4.6	4.8	4.8	**4.8**
Overall Appearance						
100	3.5	4.0	4.0	4.0	3.8	**5.0**
75	2.7	3.3	3.7	3.7	3.7	**4.3**
50	3.0	3.6	3.8	4.2	3.8	**4.5**
25	2.8	3.0	4.0	4.0	4.0	**4.4**

Table 8a. *Ceanothus* 'Yankee Point' average monthly ratings in clay loam soil on 4 levels of management allowable depletion following spring planting in 2016.

CLAY LOAM	May	June	July	Aug	Sept	Oct
Foliage						
100	3.2	4.3	4.0	4.7	5.0	**5.0**
75	4.2	4.3	4.5	4.0	4.0	**4.2**
50	3.7	4.0	3.3	2.8	2.3	**3.3**
25	2.3	3.0	3.5	2.5	2.5	**4.0**
Flowering						
100	0.0	0.0	1.0	3.0	0.0	**1.0**
75	1.5	1.7	5.0	4.0	2.5	**1.5**
50	0.0	0.0	0.0	0.0	0.0	**5.0**
25	3.5	2.0	3.0	3.5	3.0	**1.5**
Pest Tolerance						
100	5.0	5.0	5.0	5.0	5.0	**5.0**
75	5.0	5.0	5.0	5.0	5.0	**5.0**
50	5.0	5.0	5.0	4.3	4.3	**4.5**
25	5.0	5.0	5.0	5.0	5.0	**5.0**
Disease Resistance						
100	5.0	5.0	5.0	5.0	5.0	**5.0**
75	5.0	5.0	5.0	5.0	5.0	**5.0**
50	5.0	5.0	5.0	5.0	5.0	**5.0**
25	5.0	5.0	5.0	5.0	5.0	**5.0**
Vigor						
100	2.7	3.3	2.8	3.3	4.0	**4.0**
75	3.2	3.5	3.7	2.8	2.8	**3.2**
50	2.8	2.7	2.3	2.5	2.3	**3.3**
25	2.2	2.8	3.5	4.0	4.0	**5.0**
Overall Appearance						
100	2.5	3.3	3.3	3.3	3.8	**3.7**
75	3.0	3.3	3.3	3.0	2.8	**3.0**
50	2.8	2.7	3.0	2.3	2.0	**3.3**
25	2.2	3.0	3.5	3.0	3.3	**4.0**

Table 8b. *Ceanothus* 'Yankee Point' average monthly ratings in sandy loam soil on 4 levels of management allowable depletion following spring planting in 2016.

SANDY LOAM	May	June	July	Aug	Sept	Oct
Foliage						
100	3.8	3.8	4.0	4.0	3.8	**3.5**
75	4.8	4.5	5.0	4.8	4.7	**4.3**
50	4.2	4.7	4.7	4.3	4.0	**3.3**
25	4.7	4.5	4.5	4.2	4.5	**4.0**
Flowering						
100	0.0	0.0	0.0	0.0	0.0	**0.0**
75	0.7	1.0	1.2	1.7	1.7	**1.7**
50	0.0	0.0	0.0	0.0	0.0	**0.3**
25	0.7	1.7	1.7	1.7	1.7	**3.3**
Pest Tolerance						
100	4.8	4.7	5.0	4.8	5.0	**5.0**
75	4.8	4.8	5.0	5.0	5.0	**5.0**
50	5.0	5.0	5.0	5.0	5.0	**5.0**
25	5.0	4.8	4.8	5.0	5.0	**5.0**
Disease Resistance						
100	4.3	4.0	4.2	4.5	4.5	**4.5**
75	5.0	5.0	5.0	4.8	4.8	**5.0**
50	4.7	4.8	4.7	4.7	4.7	**4.5**
25	4.8	4.8	4.7	4.7	5.0	**5.0**
Vigor						
100	3.0	3.7	3.5	4.0	3.5	**3.5**
75	3.7	4.2	4.0	4.3	4.0	**4.2**
50	3.3	4.3	4.5	4.0	3.8	**3.5**
25	3.7	4.3	4.7	4.0	4.0	**4.2**
Overall Appearance						
100	2.8	3.0	3.2	3.3	3.0	**2.8**
75	3.7	3.7	4.0	4.3	4.0	**4.2**
50	3.2	3.7	3.7	3.3	3.2	**3.2**
25	3.7	4.2	4.0	3.5	3.5	**3.5**

Table 9a. *Mimulus* 'Trish' average monthly ratings in clay loam soil on 4 levels of management allowable depletion following spring planting in 2016.

CLAY LOAM		May	June	July	Aug	Sept	Oct
Foliage							
	100	3.6	4.3	4.0	3.3	3.5	**4.3**
	75	4.7	4.7	4.3	3.8	3.7	**3.8**
	50	3.7	4.2	4.0	3.8	3.8	**4.0**
	25	3.1	2.7	3.5	3.0	2.7	**4.0**
Flowering							
	100	4.3	1.3	3.7	3.0	1.5	**1.3**
	75	2.7	2.0	2.5	2.0	2.8	**1.8**
	50	2.8	1.5	4.3	2.0	2.0	**1.7**
	25	2.3	2.5	2.7	2.3	2.0	**1.3**
Pest Tolerance							
	100	5.0	5.0	5.0	5.0	5.0	**5.0**
	75	5.0	5.0	5.0	5.0	5.0	**5.0**
	50	5.0	5.0	5.0	5.0	5.0	**5.0**
	25	5.0	5.0	5.0	5.0	5.0	**5.0**
Disease Resistance							
	100	5.0	5.0	5.0	5.0	5.0	**5.0**
	75	5.0	5.0	5.0	5.0	5.0	**5.0**
	50	5.0	5.0	5.0	5.0	5.0	**5.0**
	25	5.0	5.0	5.0	5.0	5.0	**5.0**
Vigor							
	100	2.8	3.5	3.3	2.5	2.5	**3.8**
	75	2.8	3.0	3.0	3.0	2.8	**3.7**
	50	2.8	3.2	3.4	3.2	3.0	**3.3**
	25	2.8	2.7	2.8	2.8	3.0	**3.5**
Overall Appearance							
	100	3.2	3.3	3.3	2.3	3.0	**3.3**
	75	2.8	2.9	3.2	3.0	3.2	**3.5**
	50	3.0	2.8	3.6	3.0	3.1	**3.0**
	25	2.7	2.5	2.8	2.5	2.3	**3.3**

Table 9b. *Mimulus* 'Trish' average monthly ratings in sandy loam soil on 4 levels of management allowable depletion following spring planting in 2016.

SANDY LOAM		May	June	July	Aug	Sept	Oct
Foliage							
	100	4.5	4.8	4.7	5.0	4.3	**4.0**
	75	4.2	4.5	4.7	4.5	4.5	**4.3**
	50	4.6	4.6	4.6	4.6	4.2	**3.8**
	25	4.6	4.4	4.4	3.8	4.2	**4.8**
Flowering							
	100	2.7	3.0	3.2	3.3	3.2	**2.8**
	75	1.2	3.0	3.0	2.8	3.2	**2.7**
	50	2.0	2.5	3.0	2.3	3.0	**2.8**
	25	2.6	4.0	3.8	4.0	3.2	**3.5**
Pest Tolerance							
	100	5.0	5.0	5.0	5.0	5.0	**5.0**
	75	4.7	5.0	5.0	5.0	4.8	**5.0**
	50	5.0	4.8	5.0	5.0	5.0	**5.0**
	25	5.0	4.6	5.0	5.0	5.0	**5.0**
Disease Resistance							
	100	5.0	5.0	4.7	5.0	5.0	**5.0**
	75	5.0	4.7	4.8	4.8	5.0	**5.0**
	50	4.8	4.6	4.6	4.8	4.8	**5.0**
	25	5.0	4.8	4.4	4.4	4.8	**5.0**
Vigor							
	100	4.0	4.5	4.7	4.8	4.5	**4.7**
	75	3.3	3.7	4.8	4.3	4.0	**4.5**
	50	3.4	4.4	4.6	4.0	3.8	**4.0**
	25	3.6	4.8	4.4	4.4	4.0	**4.3**
Overall Appearance							
	100	3.7	4.3	4.3	4.7	4.2	**4.2**
	75	3.3	3.7	4.8	4.3	4.0	**4.5**
	50	3.4	4.4	4.6	4.0	3.8	**4.0**
	25	3.6	4.8	4.4	4.4	4.0	**4.3**

Table 10a. *Rhamnus californica* 'Mound San Bruno' average monthly ratings in clay loam soil on 4 levels of management allowable depletion following spring planting in 2016.

CLAY LOAM		May	June	July	Aug	Sept	Oct
Foliage							
	100	4.5	5.0	4.3	4.3	5.0	**5.0**
	75	3.8	4.4	4.8	4.5	4.3	**4.5**
	50	4.7	4.3	4.8	4.2	4.6	**5.0**
	25	4.3	4.8	4.8	4.2	3.8	**3.3**
Flowering							
	100	0.0	0.0	0.0	0.0	0.0	**0.0**
	75	0.0	0.0	0.0	0.0	0.0	**0.8**
	50	0.0	0.2	0.6	0.0	0.0	**0.0**
	25	0.5	0.7	0.8	0.0	0.7	**2.7**
Pest Tolerance							
	100	5.0	5.0	5.0	5.0	5.0	**5.0**
	75	5.0	5.0	5.0	4.3	4.3	**4.5**
	50	5.0	5.0	5.0	5.0	5.0	**5.0**
	25	5.0	5.0	5.0	4.3	4.3	**4.0**
Disease Resistance							
	100	5.0	5.0	5.0	5.0	5.0	**5.0**
	75	5.0	5.0	5.0	5.0	5.0	**5.0**
	50	5.0	5.0	5.0	5.0	5.0	**5.0**
	25	5.0	5.0	5.0	5.0	5.0	**5.0**
Vigor							
	100	2.8	3.2	3.5	3.8	3.3	**4.3**
	75	2.5	3.2	4.0	4.3	3.3	**4.5**
	50	3.3	3.2	3.6	4.0	3.2	**3.4**
	25	3.5	3.7	4.0	4.2	3.8	**4.0**
Overall Appearance							
	100	2.8	3.4	3.3	3.5	3.7	**3.7**
	75	2.7	3.2	3.5	3.8	3.1	**4.0**
	50	3.0	3.2	3.6	3.6	3.2	**3.8**
	25	3.3	3.6	4.3	3.4	3.6	**4.0**

Table 10b. *Rhamnus californica* 'Mound San Bruno' average monthly ratings in sandy loam soil on 4 levels of management allowable depletion following spring planting in 2016.

SANDY LOAM		May	June	July	Aug	Sept	Oct
Foliage							
	100	4.3	4.2	4.3	4.2	4.2	**4.5**
	75	4.7	4.3	4.3	4.3	4.7	**4.7**
	50	4.3	4.3	4.3	4.7	4.7	**4.8**
	25	4.3	3.7	4.7	4.3	4.7	**4.8**
Flowering							
	100	0.0	0.0	0.0	0.0	0.0	**0.0**
	75	0.0	0.0	0.0	0.0	0.0	**0.3**
	50	0.5	0.0	0.0	0.0	0.0	**0.0**
	25	0.0	0.8	0.8	0.8	0.8	**1.7**
Pest Tolerance							
	100	4.5	4.3	4.5	4.7	4.7	**5.0**
	75	4.8	4.5	5.0	4.8	4.8	**5.0**
	50	4.7	4.3	5.0	4.8	4.7	**5.0**
	25	4.5	4.7	4.8	13.2	4.8	**5.0**
Disease Resistance							
	100	4.8	4.8	4.8	4.8	5.0	**5.0**
	75	5.0	4.8	4.5	4.7	4.8	**5.0**
	50	4.8	4.8	4.5	4.8	4.8	**5.0**
	25	4.8	4.8	5.0	4.7	5.0	**5.0**
Vigor							
	100	3.3	3.3	3.7	3.3	3.3	**3.5**
	75	3.5	3.7	3.5	3.7	3.7	**4.0**
	50	3.8	3.7	3.7	3.5	3.5	**4.2**
	25	3.3	3.5	4.0	3.8	3.7	**4.3**
Overall Appearance							
	100	3.7	3.7	3.7	4.3	3.7	**4.0**
	75	3.5	3.7	3.5	3.7	3.7	**4.0**
	50	3.8	3.7	3.7	3.5	3.5	**4.2**
	25	3.3	3.5	4.0	3.8	3.7	**4.3**

Figure 1a. *Arctostaphylos* 'Emerald Carpet' in September 2016 on 50% MAD in Davis, CA. Mild chlorosis is visible.

Figure 1b. *Arctostaphylos* 'Emerald Carpet' in September 2016 on 75% MAD in Woodbridge, CA.

Figure 2a. *Baccharis* 'Pigeon Point' in September 2016 on 100% MAD in Davis, CA.

Figure 2b. *Baccharis* 'Pigeon Point' in September 2016 on 100% MAD in Woodbridge, CA.

Figure 3a. *Ceanothus* 'Yankee Point' in September 2016 on 75% MAD in Davis, CA.

Figure 3b. *Ceanothus* 'Yankee Point' in September 2016 on 75% MAD in Woodbridge, CA.

Figure 4a. *Mimulus* 'Trish' in September 2016 on 75% MAD in Davis, CA.

Figure 4b. *Mimulus* 'Trish' in September 2016 on 75% MAD in Woodbridge, CA.

Figure 5a. *Rhamnus* 'Mound San Bruno' in September 2016 on 25% MAD in Davis, CA.

Figure 5b. *Rhamnus* 'Mound San Bruno' in September 2016 on 25% MAD in Woodbridge, CA.